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RECENT ADVANCES IN GEOLOGY.*

BY J. W. FOSTER, LL. D.

Mr. President, and Gentlemen of the American Association for the Advancement of Science:—

THERE is an article contained in our Constitution which requires the retiring President to address the Association in general meeting; and custom has prescribed that he select for his theme some new and important discoveries in science, or some new inventions and processes in the arts.

It is in the discharge of this duty that I appear before you on this occasion, and solicit your attention for the passing hour. So vast is the domain of science, and so numerous have become its cultivators in almost every part of the world, that, even if I had the capacity, the labor of embodying the results of a single year, in a brief address, would be a mere accumulation of details devoid of that spirit which gives them value—generalization.

I shall, therefore, restrict myself to the researches which have been made in those departments of science which with me have been the subjects of special investigation; and shall

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*Address of the retiring president of the American Association for the Advancement of Science, J. W. Foster, LL.D., delivered at Troy, New York, on the evening of August 18, 1870.

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seek to set forth what others have accomplished, rather than to advance original views.

It will be found that, throughout all time, since the earth became fitted for the habitation of organic life, that there have been great cycles of heat and cold, and that these cycles have exercised a marked influence in the modification of all terrestrial forms. To traverse the whole ground, would employ too much time; and I shall, therefore, restrict myself to the changes which barely antedate the Human Epoch.

We know that the Tertiary Age, so far, at least, as related to the northern hemisphere, was characterized by a warm and equable climate, extending even to the Polar Sea. Where now blooms the Andromeda close by banks of perpetual snow, at that time grew a luxuriant forest vegetation. McClure's sledging party gathered fragments of fossil wood, acorns, and fir cones in the interior of Banks's Land, far within the limits of the Arctic Circle. As high as latitude 70° N. in Greenland, large forests lie prostrate and encased in ice. At Disco Island, the northern verge of European settlement, the strata are full of the trunks, branches, leaves, and even the seeds and fruit-cones of trees, comprising firs, sequoias, elms, magnolias, and laurels,—a vegetation characteristic of the Miocene Period of Central Europe. Professor Heer particularly notices the *Sequoia Langsdorfii*, which is very closely allied to the *Sequoia sempervirens* of the Coast Range of California.

Spitzbergen was clothed with a forest vegetation equally luxuriant, amongst which the Swedish naturalists recognize the swamp-cypress (*Taxodium dubium*) in a fossilized state, at Bell's Sound (76° N.), and the plantain and linden in King's Bay (78° and 79° N.). The same Sequoia was observed by Sir John Richardson within the Arctic Circle west of MacKenzie River. The lignite beds of Iceland have yielded to the botanists, Steenstrup and Heer, fifteen arborescent forms identical with the Miocene plants of Europe.

In the flora of the Great Lignite Basin of Nebraska, which is referred to the Miocene age, Hayden has detected the oak, the tulip or poplar, the elm and walnut, and a true fan-palm, with a leaf-spread of twelve feet;—all, however, of extinct species. These forms he regards as characteristic of a sub-tropical climate, such as now prevails in the Gulf States. The fan-palm (*Sabal Campbellii*) is the representative of the *Sabal major* of the European Tertiaries, and the *Sabal palmetto* of our Southern States.

The *Cinnamonium*, an unquestioned tropical type, while not thus far detected in the Missouri Basin, has been found by Lesquereaux in the Cretaceous (?) beds of Bellingham Bay, on our Northwestern coast; in the Eocene of the Lower Mississippi, and in the lignite beds of Vermont.

Professor Newberry, in a review of the flora of the Cretaceous and Tertiary Ages of North America, thus remarks:—

"We have, therefore, negative evidence, though it may be reversed at an early day by further observations, that the climate of the interior of our continent, during the Tertiary Age, was somewhat warmer than during the Cretaceous Period; and that during both the same relative differences of climate prevailed between the western and central portions that exist at the present day."

The Drift Epoch was ushered in by a marked change in physical influences, by which the whole flora of the extreme northern hemisphere was so far affected that certain forms were blotted out of existence, while other forms were forced to seek, by migration, a more congenial climate, and accommodate themselves to altered conditions. In the higher regions we find a predominating growth of mosses and saxifrages, and at the southern limits of the Drift a buried vegetation of an Alpine character.

If we examine the faunæ of the two epochs—particularly the land animals which we may suppose to be peculiarly susceptible to atmospheric changes—we shall find that there was a marked modification of forms. Dr. Leidy, in his late work on the extinct mammalian faunæ of Dakota and Nebraska, states that, of the thirty-two genera of Miocene animals, not one occurs in the Quaternary formation of North America. In comparing the Miocene and Pliocene faunæ with each other, as represented mainly by the remains from the Mauvaises Terres and the Niobrara River, scarcely a genus is common to both. "In view," he continues, "of the consecutive order and close approximation of position of the two formations and faunæ, such exclusiveness would hardly have been suspected." The greater similitude of the Miocene and Pliocene faunæ with the contemporaneous faunæ of the Old World, has led him to suggest that the North American continent was peopled, during the Tertiary Epoch, from the West. "Perhaps this latter extension," he continues, "occurred from a continent whose area now forms the bottom of the Pacific Ocean, and whose Tertiary faunæ is now represented east and west by the fossil remains of America on the one hand, and of Asia, with its peninsula, Europe, on the other."

The topographical features of the two continents and the hydrographical soundings of the two oceans, render this supposition probable. Between Ireland and Newfoundland there is a great plateau, which an elevation of the earth's crust to the extent of a few thousand feet would convert into dry land; and Behring's Straits, which now separate Asia and North America, are, at their narrowest points, but thirty miles wide, and their shallowest depth is but twenty-five fathoms.

And here the palæontologist comes to the aid of the hydrographer, and, by their joint labors, the one renders probable what the other has conjectured as possible—the former union of the two hemispheres. Zoology would indicate that such was the fact during the Pliocene Epoch, in which will probably be found the origin of those mammalian types contemporary with the elder man, and represented by the extinct Proboscidians and Ruminants. None of these large animals could probably have passed over the straits which now divide these regions, and the close alliance in form would indicate a common origin. We infer, therefore, that the subsidence during the Drift Epoch cut off the communication between the two hemispheres, and the refrigeration which then took place, served to disperse the colossal animals, who sought by migration to lower latitudes a climate congenial to their nature.

As in Europe we find the remains of these northern types intermingled with those of an African type—the hippopotamus, which in his summer migrations strayed as far north as England; so on this continent we had, during this epoch, the great sloths, represented by the megalonyx and mylodon, whose congeners at this time exist in South America. Thus there was an inosculation, so to speak, of two distinct and contemporaneous faunæ.

It is an inquiry of the highest interest—perhaps as much so as any connected with the physical history of the past: How far has man been a witness of these stupendous changes? It is not until towards the close of the Drift Epoch, that we are enabled to detect unmistakable signs of his works, although there are not wanting proofs which would refer his origin to an earlier date—the Pliocene. So numerous and well-attested are the facts, that we must now regard him as the contemporary of many of the great mammals which have ceased to exist, and the subject of physical conditions very different from what now prevail. To account for these changes requires the lapse of a longer period of time than has heretofore been assigned to his existence upon earth.

Thus within a few years has been opened a sphere of investigation which has enlisted a large class of able observers, and their labors have thrown a flood of light upon the origin of our race. Ethnography has become aggrandized into one of the noblest of sciences. However conflicting these revelations may be to our preconceived notions, they must not hereafter be disregarded in treating of the past and present condition of humanity. We must weigh the value of observations and press them to legitimate conclusions. The investigator at this day is not to be trammelled, in the language of Humboldt, by "an assemblage of dogmas bequeathed from one age to another"—by "a physical philosophy made up of popular prejudices."

The periods of the prehistoric man have been divided by M. Lartet, into two ages :—

1. The Stone Age, and (2) the Metal Age.

The Stone Age has been subdivided into three epochs.

1. That of the extinct animals, such as the mammoth and cave-bear.

2. That of the migrated existing animals (Reindeer Epoch).

3. That of the domesticated existing animals (Polished Stone Epoch).

The Metal Age has been divided into two epochs :

1. That of Bronze, and (2) that of Iron.

The elder man differed widely from the intellectual and much-planning man of this day. The conditions of climate greatly modified his modes of thought and physical pursuits. The northern hemisphere was just emerging from a long-continued state of glaciation. The snows which had wrapped the earth as in a mantle, were melting, and the great glaciers were reluctantly retreating within the Arctic Circle. Every depression became a lake, and every lake a sea for the reception of the accumulating waters, whose resistless force swept along mud, and sand, and shingle, and fragments of rocks. As the barriers gave way, the waters cut out channels on their route to the sea, and the terraces and ridges which border our lakes and rivers are but the monuments of their erosive action. It was a sad and desolate land, to be paralleled only in the Arctic Circle. But man was not alone. On the European Continent there was a strange assemblage of animals; the elephant, with his compound clothing of wool and hair; the rhinoceros similarly protected; the cave-bear and cave-hyena; the tiger; and the great ox, not patient of toil as at this day, but fierce and indomitable. On this continent was the elephant of a closely-allied species; the lion and bear, and at least two species of the musk-ox, gigantic as compared to their modern congener.

In such a climate and on such a soil we can well imagine that agriculture formed no part of the occupation of the primitive man. He gathered not the kindly fruits of the earth, but was essentially a predaceous animal. The few skulls that have been recovered would indicate that he was low in the scale of intellectual organization—a small brain, a retreating forehead, and oblique jaws. In capacity he was below the Australian and New Zealander. In stature he was dwarfed, but was broad-shouldered and robust—the result, perhaps, of vigorous exertion and out-door exposure. He was carniverous, and, perhaps, a raw flesh-eater; for in the jaws which have been disinterred, the incisor-teeth are much worn—a peculiarity which has been noticed in those of the flesh-eating Esquimaux. This fact ought not to be cited to his disadvantage, for in an Arctic climate, where the animal heat is so rapidly abstracted, man requires a highly nitrogenous food. Thus we find our own countryman, Kane, when imprisoned in the ice of Rensselaer Harbor, resorting to raw walrus-meat, and rolling it as a sweet morsel under his tongue.

It cannot be gainsayed, however, that man was a cannibal. In Scotland were found the bones of children which, according to Owen, bore upon them the marks of human teeth, and the evidences produced in the Archæological Congress at Copenhagen established this fact beyond controversy. He was not destitute of skill in the art of delineation, for we have restored to us, on a slab of slate, a very good profile of the great cave-bear—the earliest instance extant of pictorial representation.

But we must accord to him one redeeming trait. That homage which, in all ages and among all nations, the living pay to the dead; those ceremonies which are observed at the hour of final separation; that care which is exerted to protect the manes from all profane intrusion; and those delicate acts, prompted by love or affection, which, we fondly hope, will smooth the passage of the parting spirit to the happy land—all these observances our rude ancestors maintained. These facts show that, deep as man may sink in barbarism, brutal as he may become in his instincts, there is still a redeeming spirit which prompts to higher aspirations, and that to him, even, there is no belief so dreary as that of utter annihilation.

Perhaps, among the existing tribes of the human race in the Arctic Highlander, as described by Sherard Osborn, we have the nearest approach to the prehistoric man:—

> "Although dwarfed in stature, they are thick-set, strong-limbed, deep-chested, and base-voiced, and capable of vigorous and prolonged exertion. * * I cannot discover an instance of their ever having been seen to partake of a single herb, grass, or berry, grown on shore. Of vegetables and cereals, they have of course no conception, and I know of no other people on the earth's surface, who are thus entirely carniverous."

After the lapse of a period whose interval cannot be measured, the great animals which characterized the dawn of the Human Epoch, began to disappear, and were replaced by other forms of diminished size, but of improved type. Among these, on the European continent, were the reindeer, the musk-ox, the stag, the bison, and urus, together with the horse, not distinguishable from the existing species. The reindeer and musk-ox, which only thrive in a cold climate, not only occupied England, but wandered as far south in France as the shores of the Mediterranean and the slopes of the Pyrenees, which interposed effectual barriers to their further progress.

The reindeer must have existed in vast herds, and to the primeval man have proved the most useful of animals.

Every portion of the carcase was economized. His flesh furnished food; his skin, clothing; his sinews, thread; and his horns were fashioned into harpoons, javelins, and sockets for the reception of spearheads and hatchets.

On this continent we find the musk-ox and reindeer, identical in species with the European forms, in a fossilized state. The reindeer ranged as far south as Kentucky and New Jersey, but the existing musk-ox has not been found fossilized outside of his present limits. The Böotherium, however, which exceeded him in size, and to which he was closely allied, had a range co-extensive with the reindeer. The stag (*Cervus alces*) and the bison (*B. latifrons*), were in existence, while the horse, which is abundantly represented in the Pliocene, and is continued into the Quaternary Period, had become extinct before the discovery of America. His remains are found in Eschscholtz Bay (latitude 66° 20′ North) in connection with those of the *Elephas primigenus*, the urus, deer, and musk-ox, embedded in a deposit of clay and fine micaceous sand. The rhinoceros (*R. merianus*) appears in the Miocene of Texas, and is represented in the Pliocene of the Upper Missouri as *R. crassus*, and in the same formation in California as *R. hesperius;* but thus far the *Rhinoceros tichorhinus* so intimately associated with the great Proboscidians of Europe, has not, to my knowledge, been found in North America. In addition to these forms may be mentioned the great mastodon, which came into being subsequent to the elephant, and survived his extinction.

The fact of the existence of the mammoth or mastodon, was certainly known to the founders of the cities of Central America, for in more than one instance there is graven with elaborate care, on the walls of their structures, the form of a Proboscidian, which cannot be mistaken for one or the other of these animals; but the works on which these delineations are made, indicate a far higher order of art than was ever attained by the prehistoric man of Europe. These delineations, I am disposed to think, are of the mastodon, and, found as they are upon the walls of stone-built palaces and temples, there is strong evidence to believe that this great Proboscidian survived almost to the Historic Period.

The men of the Reindeer Epoch made gradual advances in the industrial arts. They did not cultivate the soil, for the climate was still inhospitable. While their progenitors were content with knives flaked from flints in the form of rude fragments with cutting edges, they wrought out tools more symmetrical, but without any attempt at polishing.

They attained to a very creditable degree of artistic skill, as shown by their designs traced on tablets of ivory, and carved out of the antlers of the reindeer. We have thus represented the stag, the ibex, the horse, a reindeer couchant forming a dagger-hilt, and also the great elephant with his characteristic markings; the small oblique eye, the ponderous trunk, the recurved tusks, and the shaggy mane. The human form even is delineated. We have an ivory statuette of the female figure, and traced on a stag's horn the outline of a male figure with a caudal appendage like that which was conjectured by Lord Mondoddo, the eccentric Scotch philosopher, to appertain to the primitive man.

On this continent the evidences of the existence of man at this age, while obscure, are yet, I am disposed to believe, authentic. The human bone found in the Loess at Natchez, and the flint implements found in connection with the Missouri mastodon, may claim as high an antiquity as the oldest of the European "finds."

The discoveries in California would seem to carry back the existence of man to a remote date. As far back as 1857 Dr. C. F. Winslow sent to the Boston Natural History Society a fragment of a human cranium found in the "paydirt" in connection with the bones of the mastodon and elephant, one hundred and eighty feet below the surface of Table Mountain, California. It was in this region (Angeles, Calaveras County) that a human skull was subsequently found by a miner named James Matson in a shaft one hundred and fifty feet deep, which passed through five beds of lava and four deposits of auriferous gravel. The statements of Professor Whitney as to the authenticity of this skull have been received with extreme distrust; but does not this earlier discovery of human remains in the same formation confirm the correctness of those statements?

Our country is yet new, and it is only recently that attention has been directed to these investigations. It is hardly to be expected that a competent observer will be present at the precise time when any relic of the past is disinterred; and there is an universal feeling of doubt and distrust as to the authenticity of all such finds. With the evidence before us that both hemispheres have been subjected to the same dynamic causes, and peopled by the same races of animals, often identical in species, is it not philosophical to infer that here we shall be able to detect the traces of man and his works, reaching back to as high an antiquity as on the European continent?

The Reindeer Epoch terminates the earliest known record in the career of man. It was signalized by a series of physical events too important to be slightly passed over. The glaciers again advanced, and again the land became refrigerated; but the cold period was not so long continued, and was less intense. To this succeeded a period of warmth, and as the glaciers dissolved under its influence, there ensued a flood which swept over the lowlands and forced the cave-dwellers to flee to the high grounds. The water in Belgium, according to Dupont, rose to the height of four hundred and fifty feet, and the calcareous mud, known as the Loess, was then deposited in the Rhine Valley. The caves were also invaded, and the "bone-earth" which forms the division between two distinct faunæ, is of the same age.

It was during this epoch that the great mammals disappeared from the earth; the elephant, the rhinoceros, the cave-bear, the cave-hyena, the tiger, and the Irish stag.

The reindeer, the musk-ox, and the elk, migrated to the north where the changed conditions of climate were more congenial to their nature.

The musk-ox has disappeared from Europe, but he survives on this continent, restricted in his range to what are known as the "Barren Grounds," lying between the Welcome and Coppermine mountains. The auroch, protected by stringent laws, still survives, while the horse, domesticated by man, has vastly multiplied. The ure-ox, living through the great catastrophe, has disappeared within historical times.

The greatly augmented thickness of the Loess on this continent, would indicate that the ice action was exerted more powerfully, and its effects are traced over a larger area; and the same destruction overtook the larger quadrupeds, extending even to the gigantic sloths, who lived in a milder climate.

From this era we may date a change in the physical conditions of our planet, so far at least as relates to the northern temperate zone. The climate became milder, and the soil yielded more bountifully those seeds and fruits which contribute to human support. Man for the first time began to show signs of progress in the industrial arts. His weapons of flint were more symmetrically fashioned, and in some instances were polished. The dog became his companion, and some of the other animals were domesticated. This was the Polished stone Epoch.

In the Bronze Epoch we trace still greater advances. Man dwelt in fixed habitations. He surrounded himself with such domestic animals as the ox, horse, pig, goat, and sheep, and retained his companionship for the dog. He cultivated wheat and barley, whose flour he kneaded into bread and baked between heated stones. Apart from berries he gathered the fruits of the pear, cherry, and plum. The discovery of the art of smelting copper, and of the additional art of hardening it by a slight admixture of tin, was an immense stride towards civilization. Ere long followed the discovery of the art of iron-smelting,—a discovery which has done more to advance the welfare of our race than all others combined. Then it was that man, for the first time, was furnished with a weapon which enabled him to achieve a conquest over Nature, and this assertion will not appear extravagant when we reflect how intimately this metal is connected with all the industrial arts.

The Iron Epoch approaches so near the Historic Era, that, as forming a portion of geological history, the events are too insignificant to be dwelt upon.

The Mound-builders of our own country, in the scale of civilization, were intermediate between the Polished stone and the Bronze Epochs of Europe. They resided in towns, many of which have since become the sites of flourishing cities. They practiced agriculture, making use of maize as their chief cereal; but there was not on this continent a domestic animal who could aid them in their labors or contribute to their sustenance. Strange as it may seem, that while the Danish kitchen-middins and the Swiss refuse-heaps contain abundant traces of mammalian bones, thus far they have been but rarely detected in the mounds. They chipped with great skill the limestone-chert into spades, spear-heads and arrowheads. Out of porphyry or greenstone they wrought their hatchets and battle-axes, and these were often ground and polished. The same material, too, was often used in making pipes, which were carved into forms representing quadrupeds and birds, so faithful in detail that the species to which they belonged can be identified. The specular iron-ore of Missouri was elaborately wrought and polished into slung-shots or "plummets." They mined extensively the native copper of Lake Superior, which they beat, and perhaps smelted, into knives, chisels, spearheads, arrowheads and bracelets. They wove cloth with a regular warp and woof, out of a fibre as yet undetermined. They modelled clay into vases, water-coolers, and other utensils, and ornamented them with elaborate designs, and the human face, even, is portrayed with rare fidelity; and finally, they must have maintained an intercourse with distant and widely separated portions of the continent.

Since the close of the Reindeer Epoch the changes which have taken place in the flora and fauna of Europe have been slight. We may note, however, the disappearance of the Scotch fir (*Pinus sylvestris*) from Denmark, where it is found entombed in the peat-swamps, and the introduction of the sessile oak, which in turn is becoming supplanted by the common beech. In the Baltic the oyster flourished in places from which it is now excluded, and certain other marine forms that attained a full growth, are now dwarfed. There is an instance or two of the disappearance of mammalian forms, but this may be traced to the direct agency of man. These slight changes in physical geography have modified the distribution of animals and plants, but they have not affected, in the least, their form. Whatever changes have been observed are due to domestication.

So far as relates to our own country, there are evidences in the Great Basin and on the Colorado Plateau, that at no remote day there was a much more genial climate and a soil more productive than now prevail. This is seen in the dead forests that line the mountain side; in the waterlines of the lakes and streams high above the greatest floods; deep cañons through which now course trickling streams, but which must have formed the channels of voluminous rivers; and alluvial bottoms now bare and desolate, in which are imbedded a robust vegetation.

I have, perhaps, dwelt too long upon these changes which have so essentially modified the surface of the earth, and at the same time the destinies of our race. Had an Arctic climate continued to prevail over what is now the temperate zone, man would have made no advance in civilization; life to him would have been a continued struggle for existence. It is only in a genial climate, and on a soil so generous as to yield with moderate exertion a support, that he can cultivate his intellect; and such culture, I need hardly affirm, is at the base of all civilization.

How great the contrast between the primitive cave-dweller and the practical man of to-day, who, availing himself of the conquests of science, subjects the forces of Nature to his will; who spans with bridges, deep chasms; who stretches his iron rails over high summits; who traverses the trackless deep with unerring course; who flashes intelligence over a hemisphere. How different from the intellectual man of to-day, who weighs the earth as in a balance; who measures the distance of the sun and assays its elements; who maps the comet's path; who penetrates the deepest mysteries of the Universe. The one was almost a brute; the other is almost a god!

While these revolutions have taken place on the surface of the earth they have, at the same time, been sufficiently powerful to modify the marine fauna in the disappearance of old and the introduction of new forms to the depth of 1,500 feet; but in the profounder abysses of the ocean, age after age, the conditions of life have remained comparatively unchanged. It is only within the past year that this interesting fact—a fact which must lead to a material modification of our previously formed views—has been prominently developed.

The soundings made as far back as 1857, over the great telegraphic plateau which stretches from Valentia to Newfoundland, disclosed in all instances a fine calcareous mud which entombed countless millions of shells belonging to the family of *Rhizopods*, and some peculiar bodies which are known as *Coccoliths* and *Coccospheres*, which were found to correspond with the organic contents of the true Cretaceous Period. In 1861, among a number of living mollusca and corals found adhering to a telegraphic cable between Algiers and Sardinia, taken up for repairs, Milne-Edwards detected certain shells which were only known as Tertiary fossils. In the same year Sars, the Swedish naturalist, described the *Rhizocrinus Lofotensis*, obtained on the Scandinavian Coast, a new and living type of Crinoidea belonging to a family characteristic of the Oolite. The soundings, prosecuted under the direction of Count de Pourtales, attached to the United States Coast Survey, between Florida and the outer edge of the Gulf Stream, have yielded important results which have been in part reported upon by de Pourtales, the elder and younger Agassiz, and Lyman.

The deep-sea dredgings prosecuted during the past year on board of her Britannic Majesty's ship Porcupine, placed at the disposal of a scientific committee, consisting of Messrs. Carpenter, Jeffrys, and Thompson, have yielded results of the highest interest. The supposition of an Azoic zone must now be abandoned. The profoundest depths of the ocean, in which the Himalayas or the Andes might be engulfed, are now believed to be inhabited, and inhabited, too, by organic forms which, since the dawn of the Cretaceous Age, have undergone no considerable modification. The littoral deposits, on the other hand show the most marked diversities in organic forms. In one sense, as declared by Dr. Carpenter, we are living in the Cretaceous Age; in another, since the close of that age we have witnessed repeated dispersions and modifications of organic forms.

Dr. Wyville Thompson, generalizing on these facts, says that there is no direct evidence that oscillations have taken place in the Northern Atlantic greater than 1,500 feet since the commencement of the Mesozoic Period, and that the great depressions in the Pacific and Atlantic oceans are due to causes that acted before that period.

"There have been," he continues, "constant minor oscillations; but the beds formed during periods of depression, but now exposed by an upheaval of this minor character, are comparatively local and shallow-water beds, as shown by the nature and richness of their fauna."

The dredgings which have been made in the fresh-water lakes of high northern latitudes have proved of equal interest. In the Swedish lakes, Wetersee and Wenersee, have lately been discovered crustacea which, though differing from those now living in the sea, are clearly related to marine forms of a northern and even Arctic character. Thus have been found the *Mysis relicta*, whose congeners live altogether in the sea, and those resembling the species in the most northern latitudes; the *Gammarius loricatus* thus far found only in the Arctic Ocean, Baffin's Bay, Greenland, and Spitzbergen; the *Idothea entomon*, in the Arctic Ocean and the Baltic Sea; and the *Pontoporcia affinis*, still found in the Baltic, but whose related species occur in the Greenland seas. These lakes are three hundred feet above the sea-level; but these results show that at no remote day they communicated with the ocean, and were originally tenanted by a marine fauna of an Arctic type. As these waters became first brackish and then fresh, most of the forms died out during the transition, leaving in the depths a few crustacea which correspond in part to the species in the Baltic, and in part to those of the Arctic Ocean.

Within the past year Dr. Stimpson has obtained results equally interesting, from dredgings brought up from the deeper parts of Lake Michigan. The lake-level is five hundred and eighty-three feet above the ocean, and the greatest depths extend below that line. At the depth of sixty fathoms he obtained a *Mysis* which, although not specifically identical with the Swedish form, is closely allied, and its occurrence authorizes us to draw the same conclusions as to the marine character in former times of the Great Lakes, which the Swedish physicists have arrived at as to the former condition of their own.

Much discussion has been had in former years, and even in this Association, as to the nature of these lake waters during the Glacial Age. It is well known that on the borders of Lake Champlain, and at intervals along the St. Lawrence from Quebec to Kingston, and up the Ottawa, the terraces attaining an extreme height of between four hundred and five hundred feet, contain marine remains; but when we pass over into the Great Lake-basin, these remains disappear. Hence it has been inferred that, at that time, as now, the Great Lakes were filled with fresh water; but the discoveries of Dr. Stimpson, I think, disprove the correctness of this inference; and further discoveries may show that these lakes formerly had communication, not only with the Atlantic through the St. Lawrence, but with the Arctic Ocean through Hudson Bay.

We are now led to the inquiry: What has caused these great changes of temperature, affecting the whole economy of terrestial life? Between the Arctic an Antarctic regions, there are great diversities of climate and physical conditions. The one is characterized by a vast expanse of land, and the other by a vast expanse of ocean. The one enjoys a short-lived summer in which the flowers blossom and fructify; in the other reigns unmitigated winter, and even mosses and lichens are absent. In the one the reindeer and musk-ox are hunted to the verge of the sea; in the other, animal life disappears below latitude 56 deg. Man has been able to penetrate North to 82 deg., 40 min., 30 sec., or within nearly five hundred miles of the pole; but to the south he has only reached 78 deg., 10 min., or about eight hundred and fifty miles.

There are several causes which combine to produce this result. The great continental masses which characterize the northern hemisphere, warmed by the summer sun, radiate heat into surrounding space, while the narrow expanse of land in the Antarctic circle, bathed by chilled waters, and encased in ice, acts as a refrigerator of the atmosphere. Besides, as we shall hereafter show, owing to the earth's movement, the southern summer is shorter by at least eight days, and the amount of heat received during that period by the northern hemisphere cannot but exert an appreciable influence. The Arctic region, then, enjoys a milder climate than it would if, as in the Drift Epoch, it were submerged to the depth of at least two thousand feet. In the Great Year of astronomers, the southern pole, after having passed through its great winter solstice, is now entering upon its summer climate.

Lyell has conjectured that these phenomena are due to a different distribution of land and water, combined with a different distribution of oceanic currents; but with an expanse of land occupying almost the whole of the northern hemisphere, and with the Gulf-stream diffusing its warm breath over the western coast of Europe, and the Japan Current over the western coast of America, we find that the domain of ice and snow remains fixed; and we can conceive of no conditions, dependent upon these causes, whereby the *Cinnamonium* should again flourish at Bellingham Bay, or the *Sequoia* on the Greenland coast.

Others have inferred that these great cycles of warmth and cold may be due to the increased or diminished heat transmitted from the interior of the earth. If we adopt the theory of a cooling globe, there must have lapsed a very considerable period between the time when it passed from an incandescent state and when it became fitted for the sustenance of organic forms. Sir William Thompson, basing his observations on the well known laws of heat and conservation of energy, infers that it has only been habitable within the last one hundred millions of years. It is, then, if his estimates be true, that within this interval we are to include all the changes in the organic world — the floræ and faunæ which have successively come into being, and have successively displaced each other.

In the process of solidification the earth is supposed long ago to have arrived at that stage when the radiation from the cooling surface is no greater than that derived from the sun, and therefore, a stable temperature has been established. We would infer, then, that any violent reaction of the interior upon the external crust, would affect more sensibly the deep-sea animals than those dwelling on the land; but the investigations which I have cited, show that while the sea-fauna has undergone slight modifications since the dawn of the Cretaceous Epoch, the land-fauna has been subjected to the most marked deviations.

May not, then, these fluctuations of temperature be due to causes which operate from the exterior? It is necessary to assume that, throughout the lapse of all time, our planet has occupied its present relation to the sun, or the solar system? Is not the recession of Sirius, which is now going on, an argument against the fixity of the siderial heavens?

We are assured that ours is not a central sun, but one in the great possession of stars which is sweeping towards the constellation Hercules; and that in the region of either there are spaces of densely-clustered stars, and other spaces which are comparatively barren. Now every star is a sun, emitting light and heat, a portion of which is transmitted to us. Our planet at this time is moving through one of those starless spaces, and therefore is not in a position to receive the full influence of such a cause. The distinguished Swiss botanist, Heer, to whom we are so largely indebted for our knowledge of the Miocene flora, has suggested that it is to this source rather than to telluric causes we are to resort to explain the varying distribution of temperature as manifested in past geological times.

Again: Have we the right to assume that, throughout all past ages, the poles of our planet have pointed in the same direction? We can conceive that, if its axis were to form with the plane of the ecliptic, the same angle which it now forms with the equatorial plane, there would ensue an entire change of climate, and consequently of organic forms. Why should the astronomer insist on the immutability of the siderial system, when to the geologist is unfolded a record of seas displaced and continents elevated; of great cycles of heat and cold; of the disappearance of old, and the appearance of new forms of organic life? Change, not constancy, is inscribed on every leaf in the volume of Nature.

I am not a believer in the doctrine of multiplied shocks. I would not, in the explanation of natural phenomena, resort to blind catastrophes. But is there not behind all, and over all, and pervading all, a great governing principle to whose operation we can refer these changes? Does it not exist in the celestial mechanism itself? To the solution of this problem the attention of several physicists has been directed.

The speculations of the French savant, Adhèmar, are not altogether to be overlooked, based as they are on the precession of the equinoxes and the movement of the apsides; a movement which, I believe, was unknown to the elder astronomers. If we compare the movement of the earth with the stars, it requires the lapse of 25,000 years to bring the equinox to correspond with the same point in space it now occupies; but the orbit itself being movable, this period is reduced to about 21,000 years. This is called the Great Year, being the measure of time before the winter solstice will again exactly coincide with the *perihelion*, and the summer solstice with the *aphelion*, and before the seasons will again harmonize with the same points of the terrestrial orbit.

The earth, at this time, approaches nearest the sun in the northern hemisphere during autumn and winter, and it is only when it recedes the farthest from the source of heat that the northern hemisphere receives the full effect of its vivifying warmth. As the earth between the vernal and autumnal equinox traverses a longer circuit than during the other half of the year, and also experiences an accelerated movement as it draws near the sun, the result is, that the northern summer is longer than the southern by about eight days; but after the lapse of ten thousand five hundred years these conditions will be reversed. It was in the year 1248, according to Adhèmar, that the Great Northern Summer culminated, since which time it has continued to decrease, and that decrease will go on until the year 11,748, when it will have attained its maximum.

This compound movement, the precession of the equinoxes and the shifting of the line of apsides, it is claimed, exerts a marked influence in the distribution of the earth's temperature. While the Great Winter prevails at the north pole, the refrigeration is so excessive that the heats of summer are insufficient to melt the snow and ice precipitated during the winter, and hence, year after year and century after century, they go on accumulating, until the circumpolar region is in a state of glaciation, and the added weight becomes sufficient to displace the centre of gravity, which would be equivalent to a subsidence at one pole and an elevation at the other. M. Adhèmar has even calculated the extent of this movement, and states that it would amount to about 5,500 feet. Now, let it be borne in mind that Professor Ramsey has shown that in Wales the submergence of the land during the Drift Epoch amounted to 2,300 feet, and our own observations show that in the northern portions of this country the glacial action proper may be traced to the height of 2,000 feet; although there were mountains which served as radiating centres, on whose flanks the Drift action may be traced much higher. These geographical points, roughly estimated, are about midway between the equator and the pole, and the extent of the subsidence would correspond very well with the calculations before referred to.

In the year 1248, the Great Winter terminated at the south pole, where for 10,500 years the accumulation of snow and ice had been going on, attended with the phenomena which we have described. "Here then," says M. Julien, an advocate of this theory, "is an irresistible force which, following the invariable law of the irregular precession of the equinoxes, must make the earth's centre of gravity periodically oscillate."

Mr. Croll, an English physicist, has elaborately discussed this question in a series of papers in the "Edinburgh New Philosophical Magazine," which have excited profound attention. With great labor he has prepared tables showing the amount of the earth's eccentricity for the period of three millions of years, at intervals of 10,000 years for a greater portion of that time, and 50,000 years for the remainder. He infers that a glacial period occurs when the eccentricity of the earth's orbit is at a maximum, and the solstices fall when the earth is *in perihelio* and *in aphelio;* and that only one hemisphere has a glacial climate at the same time, which occurs when the winter is *in aphelio.*

In this connection I may mention the labors of our own countryman, Mr. Stockwell, who has prepared a paper, now on file in the Smithsonian Institution, embodying his own calculations as to the earth's eccentricity for the past two millions of years.

There is such an intimate connection between the several branches of science that the researches in one field often throw light upon the obscure points in another. In the solution of this difficult problem, the geologist may invoke, and I trust not unsuccessfully, the aid of the astronomer.

That a set of causes were active during the Drift Epoch, in one hemisphere, which remained dormant in the other, admits of little doubt; and the advocates of the astronomical theory, as evidences of the shifting of vast amounts of water from one pole to the other, point to the marked differences in the topographical features of the two hemispheres. In the Austral region we meet with projecting headlands and peninsula-like terminations of continents, and groups and chains of islands in the Pacific and Indian oceans extending over vast areas, which rise up like the peaks and crests of mountains. These are the evidences of a gradually engulfed hemisphere. In the Boreal region we have wide expanses of land diversified by mountains, prairies, and plains; elevated sea-beaches and river-terraces, most conspicuously displayed on the borders of the Arctic Sea; vast oceanic shoals; a marine fauna of a northern type preserved in beds of 1,400 feet, and stratified beds of gravel and sand 2,000 feet, above the ocean-level; clusters of lakes yet retaining their bitter waters; shallow seas once salt, but each decade becoming more brackish; vast desert tracts which up to a recent time formed the ocean bed;—all these phenomena indicate a hemisphere gradually emerging from the waters. Perhaps the physicist can discern in these great periodic oscillations, the method by which Nature perpetually renews the youth of our planet, and maintains its fertility.

Gentlemen of the American Association:—The hour which, in your courtesy, had been assigned to me, has now lapsed, and I must bring these remarks to a close. The topics which have passed under review open up spheres of thought with regard to time and space too vast to be compressed within the limits of a mere oral discourse. Asserting no ability by reason of profound research to pass authoritatively on these results, may I not inquire: Have they not disclosed new paths in the great domain of Nature, which may be profitably explored jointly by the geologist and the astronomer; and is there not a probability that there will be found to exist an intimate relation between the periodic fluctuations of temperature on our planet, and the periodic pertubations to which it is subjected as a part of the solar system? Great as have been our achievements in science during the past, we profoundly believe that new triumphs await the patient observer.

VARIATIONS IN TRILLIUM AND WISTERIA.

BY THOMAS MEEHAN.

In a recent number of the "Bulletin of the Torrey Botanical Club," of New York, Mr. J. H. Hall describes a plant of *Trillium erectum*, which he has had under his observation for several years, and which produced some years white, and other years the regular brown purple flowers. I have made